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ESTIMATING SAMPLE SIZE REQUIRED TO MONITOR MARINE MAMMAL MORTALITY IN CALIFORNIA GILL-NET FISHERIES

by

Jay Barlow

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Estimating Sample Size Required to Monitor Marine Mammal Mortality in California Gill-Net Fisheries

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Abstract

Bootstrap simulations are used to estimate the statistical reliability of estimates of marine mammal mortality in California gill-net fisheries. Coefficients of variation in total mortality are calculated for levels of observer coverage ranging from 5 to 35% of the total number of sets. A coefficient of variation of 10% can be obtained if the following percentage of sets are observed: 8% for sea lions and harbor seals in set nets, 35% for harbor porpoise in set nets, and 20% for sea lions and harbor seals in drift nets. Problems exist with sampling designs that are based purely on statistical reliability. It is recommended that the biological significance of the kill should be considered in allocating limited resources to a fishery observer program.

Introduction

Recent amendments to the Marine Mammal Protection Act (MMPA) require monitoring of marine mammal mortality in fisheries with "frequent incidental taking of marine mammals". The level of coverage recommended in the legislation is 20-35% of all effort in "Category 1" fisheries (ie. those which frequently take marine mammals). If insufficient funds are available for this level of coverage, a less intensive monitoring program may be considered if it can be shown to provide statistically reliable estimation of marine mammal mortality.

The purpose of this paper is to provide a guideline for deciding what might be considered statistically reliable and to estimate the level of coverage that are needed to give this level of reliability for predominate gill-net fisheries in California.

In California, the fisheries which have been identified as Category 1 fisheries are all gill-net fisheries (I include trammel nets when referring to gill nets) (Fed. Reg. 1/27/89). These include coastal set-net fisheries for halibut and angel sharks (taking sea lions, harbor seals, and harbor porpoise) and offshore drift-net fishery for shark and swordfish (taking sea lions and harbor seals). The estimates of marine mammal mortality for the 1985-86 fishing seasons were 2050 sea lions in

set nets, 1728 harbor seals in set nets, 226 harbor porpoise in set nets, 157 sea lions in drift nets, and 158 harbor seal in drift nets (Hanan, Diamond, and Scholl 1987, 1988).

Methods

A bootstrap approach is used to calculate the coefficient of variation in estimates of total mortality for levels of observer coverage ranging from 5% to 35% of all sets. The bootstrap approach simulates the sampling procedures that have been used in the past. First, the computer generates a typical year of fishing effort based on the expected number of sets. For each set, the number of marine mammal deaths is assigned based on previous observation of the frequency of sets with zero, 1, 2, 3, etc. deaths. A sample of sets is drawn randomly from all sets from that year, and the number of total deaths is estimated as the number of observed deaths divided the fraction of sets that were observed. This process of randomly drawing a sample and estimating total mortality from that sample was repeated 500 times. The mean and variance were calculated for the 500 estimates of mortality. The coefficient of variation is estimated as the standard error of the estimate divided by the mean.

The above bootstrap approach simplifies a complex sampling problem so that only three pieces of information are needed. First is the fraction of net sets that are observed. The more sets that are observed, the more precise the estimate of mortality will be. I use a range of observation rates from 5% (corresponding to the maximum previous levels of gill-net monitoring by CDFG) to 35% (corresponding to the maximum observation rate mentioned in the amendments to the MMPA). Second is the probability of seeing zero, 1, 2, 3, etc. marine mammal deaths while observing any randomly chosen set. If deaths are rare events and are highly correlated, estimates will be less precise than if deaths are common and uncorrelated. I used frequency distribution of kills per set seen during the CDFG observer program (Table 1) to determine these probabilities. Third is the total number of sets. If there are more sets, random sampling errors will tend to cancel one another and estimates will be more precise. I used the most recent (preliminary) estimates of gill-net effort (1986-87 fishing season) to estimate the number of sets in future years (Table 1).

The simplification described above does not account for all possible sources of sampling variability. It assumes that there is no error in estimating the total number of sets and in estimating the number of animals killed in an observed set. It assumes that if an observer is placed on one vessel and observes several consecutive sets, that the mortality in those sets is

uncorrelated. It also assumes that no stratification schemes are used to reduce sampling error. Violation of these assumptions could either increase or decrease sampling error depending on many factors that cannot be accurately predicted. For the purpose of designing a sampling scheme, the simplification that I used is probably adequate.

Results

The coefficient of variation in kill estimates are given in Figure 1 as a function of the level of observation effort for 3 fishery/marine mammal groupings. The results for sea lions and harbor seals in set nets were indistinguishable and are combined in Figure 1. Likewise, the results for sea lions and harbor seals in drift nets were identical and were combined. The level of coverage which results coefficients of variation of 10% are approximately 8% for sea lions and harbor seals in set nets, 35% for harbor porpoise in set nets, and 20% for sea lions and harbor seals in drift nets.

Discussion

The amendments to the MMPA do not define what is meant by its requirement to provide "statistically reliable information" on the number of marine mammals taken by specific fisheries. One measure of the reliability of an estimate is the coefficient of variation or C.V. It is defined as the standard error divided by the mean and multiplied by 100. If error is normally distributed, 95% confidence limits can be estimated as 2 times the standard error. Thus a C.V. of 10% would mean that 95% confidence limits would be within +/- 20% of the estimate. In most biological studies, a C.V. of 10% would be considered extremely good. Depending on the study, C.V.'s of 15-20% are often considered acceptable. There is simply no standard for "statistical reliability".

In the above results, I have presented observation rates which result in C.V.'s of 10%. Although choice of this level is somewhat arbitrary, most biologists would agree that such an estimate is statistically reliable. By choosing an estimate that is well within the range of what is generally accepted as reliable, allowance is made for sources of sampling variability which occur in any real sampling program, but which were not accounted for in my simplified, simulated sampling program. Of particular concern is random error in estimating the total number of sets (this was not considered in the bootstrap estimation of C.V.'s). If other reliability levels are judged to be more appropriate, the observer coverage that is required to achieve that level can be estimated from Figure 1.

Although C.V.'s are a reasonable measure of statistical reliability, they are not necessarily a good measure of biological reliability. An example can be used to illustrate this point. Assume that 10 common dolphin (Delphinus delphis) are taken each year in drift gill nets out of a population of 100,000 common dolphins. Because dolphin mortality would be such a rare event, it is difficult to imagine any level of sampling effort that would provide a C.V. of 10% in estimates of dolphin mortality. In this case, a coefficient of variation of 100% may be sufficient to determine that gill-net mortality would not significantly affect the population of common dolphins. This example illustrates that it is important to consider the absolute magnitude of the take and the size of the population in addition to statistical reliability when designing a fishery monitoring program.

An alternative to using C.V.'s as a measure of sampling reliability would be to establish target confidence limits in terms of a fraction of the population that is affected by the fishery. As an example, it may be useful to try to estimate the number of harbor seals taken to within 2% of the harbor seal population. If this were the goal and if the population was 20,000 individuals, the 95% confidence limits for the take should be ± 400 individuals and the standard error in the estimated take should be 200 individuals. In the case of harbor seal, this corresponds to a C.V. of 10% on a total estimated kill of 2,000 individuals. Returning, however, to the common dolphin example, if the goal is to estimate the take to within 1% of the population, the standard error should be less than 500 individuals. If the true take is only 10, this level of precision would be easy to obtain. To facilitate use of this approach, standard errors are expressed in terms of numbers of individuals in Figure 2.

Another problem that was not addressed specifically in the amendments to the MMPA is whether coverage rates should be designed to estimate take of a species in a specific fishery or whether coverage rates in different fisheries can be adjusted independently to give the best estimate of take from a specific marine mammal population. For example, California set-net and drift-net fisheries take sea lions from a single population. Current data indicate that set nets are responsible for the majority of the sea lion take. It might be better to design an observer program that gave more precise estimates of take from the set-net fishery and less precise estimates of take from the drift-net fishery in order to give the highest precision in estimates of total sea lion take in California. The goals of an observer program should be defined more precisely in order to adequately design a sampling plan.

Acknowledgements

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Hanan, D. A., S. L. Diamond, and J. P. Scholl. 1988. Estimates of sea lion and harbor seal mortalities in California set net fisheries for 1983, 1984, and 1985. Final Report to National Marine Fisheries Service, Southwest Region.

Table 1. Annual number of sets and the frequency distribution of sets with a given number of observed marine mammal deaths for the 5 predominate fishery/marine mammal groupings. The number of sets are based on the 1986-87 fishing season (Diamond, pers. comm.). The number of deaths per set were based on sets that were observed during the 1983-86 fishing seasons (Hanan et al. 1988; Hanan pers. comm.).

	Number Sets	Number of Deaths per Set						
		0	1	2	3	4	5	6
Sea lions in set nets	34025	3996	156	25	4	2	1	0
Harbor seals in set nets	34025	3991	159	25	6	0	1	1
Harbor porpoise in set nets	7991	1920	43	7	1	1	0	0
Sea lions in drift nets	10330	174	6	1	0	0	0	0
Harbor seals in drift nets	10330	180	1	0	0	0	0	0

C.V. in Estimates of Mortality

California Marine Mammals

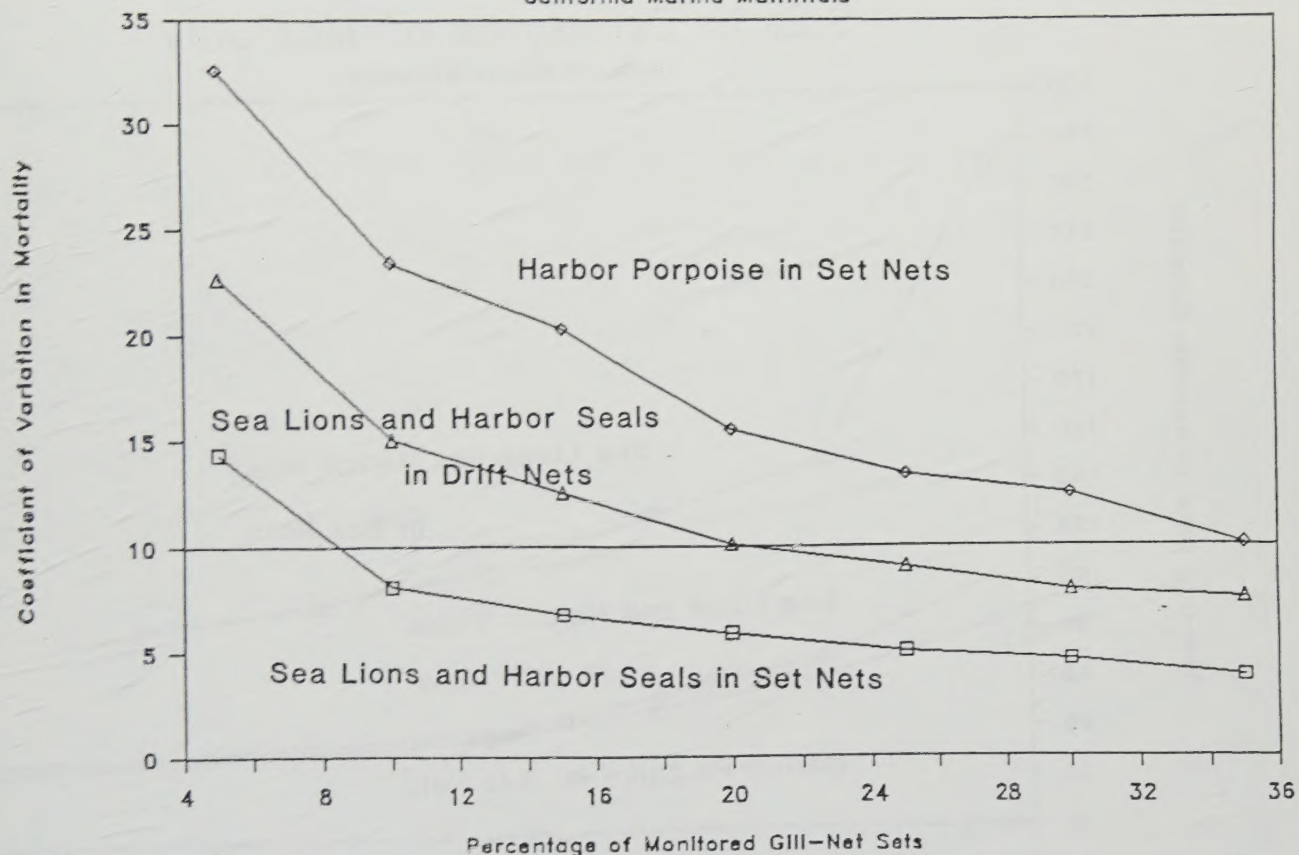


Figure 1. Coefficients of variation for estimates of marine mammal take in gill nets as a function of the level of observer coverage. Fisheries/marine mammal groups include sea lions and harbor seals in set nets (squares), harbor porpoise in set nets (diamonds), and sea lions and harbor seals in drift nets (triangles).

S.E. in Estimates of Mortality

California Marine Mammals

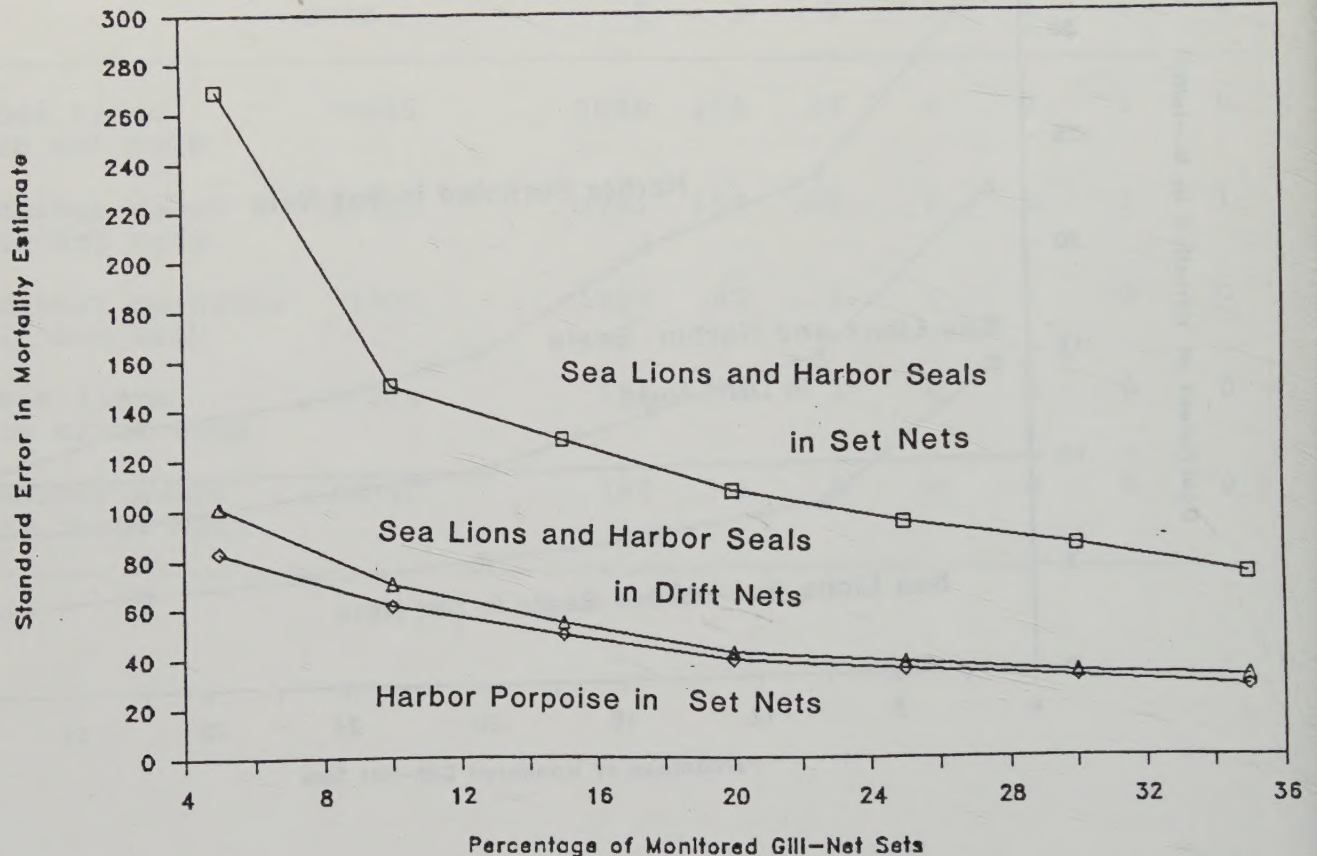


Figure 2. Standard errors (in number of individuals) for estimates of marine mammal take in gill nets as a function of the level of observer coverage. Fisheries/marine mammal groups include sea lions and harbor seals in set nets (squares), harbor porpoise in set nets (diamonds), and sea lions and harbor seals in drift nets (triangles).

